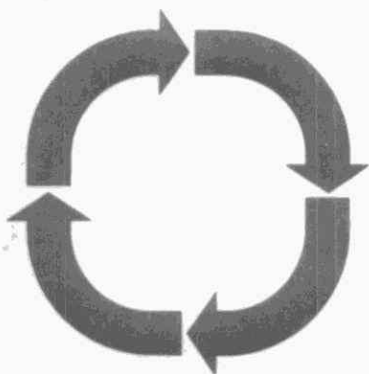




Resource Recovery



REPORT ON
DERIVATION OF ENERGY FROM REFUSE
AT WINDSOR, ONTARIO

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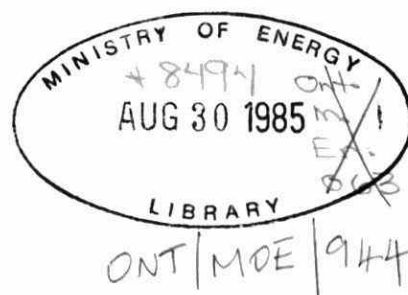
Ministry
of the
Environment

REPORT ON
DERIVATION OF ENERGY FROM REFUSE
AT WINDSOR, ONTARIO

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REPORT ON
DERIVATION OF ENERGY FROM REFUSE
AT WINDSOR, ONTARIO

1. INTRODUCTION

This Report is to be read in conjunction with the Final Report on Windsor Area Resource Recovery Study prepared by M. M. Dillon for the Ontario Ministry of the Environment. It provides supplemental information on the potential for energy recovery in Windsor, Ontario.

2. SCOPE

The objectives of this Report are to:

- Investigate existing technologies available for energy recovery from refuse as they may apply to the Windsor situation.
- Study existing large-scale energy conversion facilities in Windsor.
- Determine the applicability of any of these facilities for using refuse or any form thereof as a fuel.
- If warranted, carry out detailed studies on the most feasible option for energy recovery from refuse at Windsor.
- Prepare recommendations for further technical work (preliminary and/or final design), financial analysis and contractual considerations.
- Prepare estimates for engineering, capital and operating costs for the above recommendations.

3. METHODOLOGY

It was decided at the outset of this Study, during a meeting between senior staff of the Resource Recovery Branch of the Ontario Ministry of the Environment and M. M. Dillon, that:

- only currently proven processes for recovery of energy from refuse be investigated.
- gasification processes be given lower priority than direct combustion of the refuse or refuse-derived fuel.
- only the large energy consumers within close proximity to the proposed Resource Recovery Plant at the existing City of Windsor Solid Waste Control Centre be considered for detailed investigation. These were the Chrysler Corporation, the Ford Motor Company of Canada Ltd., Hiram Walker and Sons Distillers and Ontario Hydro's J. Clark Keith Thermal Generating Station.

Input for Section 4 of this Report was obtained from a review of current technical literature and from first-hand experience of M. M. Dillon senior staff who had previously visited several operating facilities. Mr. G. E. Humphries toured several installations in Europe. Mr. T. A. Constantine visited the facilities at Hamilton, Ontario; Montreal, Quebec; Buffalo, New York and Ames, Iowa.

For Section 5, Mr. Humphries and Mr. Constantine arranged visits to the facilities at Chrysler, Ford, Hiram Walker and the J. Clark Keith Station. As well as carrying on detailed discussions with engineering and operating personnel, extensive plant tours were arranged. The data presented was compiled from notes of observations and discussions during the visits and tours.

4. STATE OF THE ART REVIEW

4.1 GENERAL BACKGROUND INFORMATION

Over the past decade, there has been an increasing interest in the recovery of energy from refuse. A number of processes have been evolved for this purpose and some have been developed beyond the pilot or demonstration stages into full-scale operating facilities which produce a form of energy (either fuel, heat or electricity), thereby reducing demand for conventional fuels.

The following are some examples of full-scale operating facilities employing successful processes:

a) West European Practice

The burning of refuse to recover energy was pioneered in Europe. Several installations (e.g., Paris, Munich, Dusseldorf, Stuttgart, Mannheim, Berlin) now produce turbine quality steam by burning raw or coarse ground refuse on either reciprocating or travelling grates specially designed for refuse. In some installations, pulverized coal is suspension fired in adjacent furnace chambers while in others the coal is fired in the same chamber as the refuse using tangentially mounted burners. Some units are also equipped with oil or gas auxillary firing equipment. Other boiler installations employing similar grates produce low pressure steam for district heating (e.g., at Frankfurt).

Boiler tube corrosion rates, originally thought to be severe have proved to be only slightly higher than for boilers not burning refuse.

Generally, installations are equipped with electrostatic precipitators for control of fly ash particulate emissions. Sulphur dioxide emissions are very low; often one-tenth of the coal burning emission rate. (This of course is due to the low sulphur content of the refuse.)

European facilities are rated at from 30 to 100 tons of refuse per hour with single boiler ratings of from 10 to 40 tons per hour.

Metals, if recovered, are removed from the residue.

b) North American Experience - Unprepared Refuse

Facilities at Chicago and Montreal employ European designed boiler systems to burn raw refuse on either reciprocating grates (Chicago) or Von Roll type, tumble grates (at Montreal). The steam produced is not of turbine quality and because of limited heating demands, the facilities are operated only at partial capacity or steam is condensed without energy extraction.

As with European practice, these facilities include electrostatic precipitators for air pollution abatement. The residue is landfilled.

c) North American Experience - Prepared Refuse

Prepared refuse is commonly known as refuse-derived fuel (RDF). RDF generally refers to refuse which has been shredded and from which a heavy fraction containing metals, glass, rubble, etc. has been removed (usually by air classification). The resultant particle size from shredding depends upon the method of firing used for the boiler; the two common methods being either pneumatic (suspension) firing and stoker firing.

Two examples of suspension fired refuse burning boilers are at St. Louis, Missouri and Ames, Iowa. Both generate steam for turbo-electric power generation. At St. Louis, for a demonstration project at the Union Electric Company, two existing pulverized coal-fired power boilers were fitted with suspension firing equipment. The RDF was fired via ports which are adjacent to the pulverized coal burners. The rate of refuse firing is approximately ten per cent of the total fuel on an equivalent Btu basis, which amounts to about 300 T/D. No modifications to either the bottom ash handling system or the electrostatic precipitators originally designed for operation with pulverized mid-western U.S. coal-fired system were required. This demonstration project was successful enough to provide the basis for design criteria for a new 8,000 T/D processing-energy recovery project.

At Ames, Iowa, a system similar to that at St. Louis was to be used. Only one boiler is capable of being suspension

fired with refuse-derived fuel and its capacity is only about half that of the St. Louis boilers. Initial operating experience, however, showed that suspension firing presented several problems and now two smaller stoker-equipped boilers are burning the RDF which has an average size of 1 1/2". Combustion of the RDF is mainly on the grates. A unique feature of the Ames plant is that the RDF is pneumatically conveyed from the adjacent processing facility to the boiler, a distance in the order of 1,000'.

For the above type of combustion process, the RDF which consists mostly of paper and paper products, plastics, organics and wood chips must be finely ground. Typical particle size data indicates 1.5" maximum size and .375" mean size (from sieve analysis). As noted above, the particle size at Ames is somewhat greater than this. Heating values are typically in the 5,000 Btu/lb range.

An example of a combined stoker/suspension fired facility has been constructed at Hamilton, Ontario. This plant, rated at 600 tons of refuse per day, generates up to 100,000 lb/hour of steam (saturated 250 psig) and has two boilers fired by pneumatic (bark type) stokers with a good portion of the combustion occurring on travelling grates. The bottom ash handling system is a dry type with disposal adjacent to the plant. The electrostatic precipitator has

been troublesome and is currently under study for improvement. The refuse-derived fuel is produced at the adjoining processing facilities which comprise manual picking, coarse grinding and magnetic separation. The typical particle size for this form of RDF is 4" to 6" and is not too critical for this type of stoker operation. Unfortunately, most of the steam produced is condensed. The plant was originally envisaged to produce 250 psig steam for industrial and heating use. The users, however, have not materialized.

d) Recent Developments

- Gasification

Three proprietary processes have been pilot tested and have proceeded into full-scale design and construction.

These are:

The Andco-Torrax System

The Union Carbide "Purox" System

The Monsanto "Landgard" System.

All systems pyrolyze the refuse to produce a fuel gas and an inert residue.

Andco Torrax have a 100 T/D demonstration facility at Buffalo, New York and are constructing several larger scale facilities in Europe. Union Carbide has a 200 T/D demonstration facility at South Charleston, West

Virginia and will be constructing a large-scale facility for Seattle, Washington. Monsanto's 35 T/D pilot plant at St. Louis provided data for the design of a large-scale facility at Baltimore, Maryland.

The Monsanto plant which uses a horizontal kiln as a pyrolysis reactor has been plagued with problems. Both the Andco Torrax and the Union Carbide processes employ a proven tower type reactor. The Andco process produces a fuel gas with a heating value of about 85 to 100 Btu/CF which is burned in an adjacent combustion chamber. The hot gases are then passed to a waste heat boiler for steam production. The Union Carbide process, using pure oxygen instead of air in the pyrolysis reactor is capable of producing a fuel gas which has a heating value of about 350 Btu/CF and can be burned in a boiler with conventional gas firing equipment.

Both the Union Carbide and the Monsanto processes require coarse shredding (6" particle size) and can include ferrous metal recovery. The Andco Torrax system does not require shredding but can operate satisfactorily on coarse shredded refuse.

Gasification processes hold good promise of success for the future recovery of energy from solid waste.

- Densified RDF (dRDF)

A drawback of the RDF discussed previously is its extremely low bulk density generally found to vary from 2 to 9 lb/cu ft. This makes handling and transportation rather costly and environmentally disagreeable due to its light fluffy nature.

Research and development of a densified refuse-derived fuel (dRDF) is proceeding in the U.S. and one company, Combustion Equipment Associates (CEA) of New York is marketing a product in both nugget and particulate forms. To densify, the raw RDF is passed through either a pelletizer or a briquetter which produces a product with a particle size of about 1" and a bulk density of 35 to 45 lb/cu ft. Waste oil has been found to be an excellent "binder" for dRDF.

Densified RDF can be fired using spreader stokers and travelling grates or it can be pulverized in separate grinding equipment and burned in suspension with the coal using conventional equipment. The granular form could be suspension fired directly. The use of dRDF continuously on a full-scale operating unit has not yet been tried. The advantages of dRDF being similar in nature to other solid fuels such as coal (which facilitates transportation and handling) will surely result

in major full-scale trials in the near future most likely in the USA.

4.2 APPLICABILITY TO WINDSOR, ONTARIO

There is a wide variety of opinions among engineers and scientists as to the best approach to the derivation of useful energy from refuse. As can be seen from the above, turbo-electric generation of electricity is becoming an accepted method using either the water wall incinerator design common to most European installations or using conventional power boilers burning a RDF as in the U.S. The production of a fuel gas holds good promise for the future. Other schemes involve the production of steam for industrial processing and steam and/or hot water for district heating.

At Windsor, Ontario, district heating cannot be given serious consideration at this time as all commercial, industrial and institutional establishments in Windsor have their own heating plants. The most promising ultimate users of refuse generated energy are the industries or Hydro in Windsor.

Investigations of four large industries within the serviced area - Chrysler Corporation, Ford Motor Company, Hiram Walker and Sons and Ontario Hydro's J. Clark Keith were made. Each have considerable energy requirements. The private industries purchase electrical energy from Ontario

Hydro and also generate steam for process and heating use. A description of the Hydro station and the industrial steam production facilities together with a discussion on their adaptability to the use of refuse for fuel is given in the following Sections.

5. STUDY OF EXISTING FACILITIES

5.1 GENERAL

The three existing large industrial boiler plants and the Ontario Hydro Generating Station in Windsor were studied to determine existing conditions and compatibility of conversion to refuse firing.

5.2 CHRYSLER CORPORATION

Steam is supplied to the large Chrysler Centre Walker Road Complex by the main boiler house on the premises. The Tecumseh Road truck plant and the Pillette Road light truck plant have their own small package boiler facilities. At the main boiler house, steam is produced primarily for space heating. The second principal use is process heating (e.g., solutions in tanks, etc.). The typical summertime steam consumption is 100,000 lb/hr while that of the winter months is 350,000 to 400,000 lb/hr. No increase in these demands is anticipated in the foreseeable future. Through energy conservation, the company hopes to be able to save 20,000 to 30,000 lb/hr off summer demands and even more off winter demands. Chrysler are also studying the possibility of recovery of energy from solid waste generated from in-house operations (e.g., corrugate and lumber from crates, etc.) which is at present disposed of at landfills.

The total installed generation capacity of the boiler house is 560,000 lb/hr. Steam is generated at 155 psig, dry and saturated. There are a total of six boilers; five of which (ranging in age from 22 to 38 years of service) have been converted (in 1969-70) from burning crushed coal via spreader stokers on travelling grates to dual firing (oil and gas). The newest boiler which replaced one of the original 1920 vintage boilers is of the "package type" design for dual (oil and gas) firing only. This boiler was installed in 1974. All boilers except the oldest of the converted ones are rated at 100,000 lb/hr of steam at design conditions. Four of these boilers are of Babcock and Wilcox manufacture. The new package boiler is a Foster-Wheeler. The oldest boiler, of Stirling design is rated at 60,000 lb/hr.

The coal grinders, stokers and grates have been removed from the boilers and have been scrapped, as have the gravity and multi-cyclone type dust collectors. Some portions of the old coal and ash handling systems still remain in place however. These include:

- underground coal storage pits complete with traffic rated removable covers
- one bucket elevator is intact, the other has been removed

- the spreader conveyors appear to be all intact
- overhead coal bunkers (although corrosion has taken its toll of the shells)
- nozzles on bunkers for coal chutes have been blanked off and chutes have been scrapped
- the ash silo and ash load-out station are still intact but the ash conveying system is not operable.

The boilers operate on balanced draft with air preheat but no superheat. As noted previously, the pollution abatement equipment has been abandoned and removed. The stacks, which are designed to handle pairs of boilers are of free-standing steel type construction and are approximately 102' in height. They are equipped with conical end sections to augment plume rise. When burning coal, complaints about sulphur dioxide fume and occasionally particulate fall-out were received from surrounding residences.

The boiler plant area is somewhat restricted. Traffic ways which were originally used for coal delivery and ash removal by truck still exist however.

5.3 FORD MOTOR COMPANY

The entire Ford Windsor Division Complex is served by a central boiler plant located on Ford's property adjacent to Riverside Drive. Ford's steam uses, like those of Chrysler, are primarily for space heating and secondly for process heating. Ford, however, have power boilers which produce turbine quality steam (800 psig superheated to 800°F) which is fed to turbo generators that produce a portion of Ford's electrical energy. There are two 25MW generators and one 5MW generator.

The boiler/power plant is generally operated as follows. Medium pressure (175 psig) steam and low pressure (7 psig) steam is extracted from the turbines for process and space heating systems. During times of low steam demand, there may be excess steam from the turbines which requires condensing. When steam demand exceeds turbine extraction capabilities, pressure reducing stations are used to make up the difference. The typical summertime steam demand is 200,000 lb/hr of which 50,000 lb/hr is used for process and space heating and the remainder is used for power generation. The wintertime steam demand is about 375,000 to 400,000 lb/hr of which 250,000 to 275,000 lb/hr are used for process and space heating. Ordinarily only one of the 25MW generators is run, supplying one of the three main electrical busses at

Ford. No provision is made for feeding electricity generated by Ford back into the Windsor energy grid.

Indications are that Ford may retire the turbo generators from service in the near future. This would reduce steam requirements by approximately 150,000 lb/hr. No increases in either the heating or process steam demands are anticipated in the foreseeable future.

The total installed generation capacity of the boiler house is 840,000 lb/hr of superheated steam. There are a total of five boilers, four of which were installed in 1936-38 rated at 160,000 lb/hr each, and one installed in 1952 rated at 200,000 lb/hr. The boilers were all originally fired with pulverized coal and the three newest ones have been converted to dual oil/gas firing in 1971. The two oldest boilers have never been converted and consequently have not been operated since conversion. All boilers are of Combustion Engineering Superheater manufacture.

The wet ash handling systems for the three converted boilers are not operational. Most of the coal firing system is, however, still in place and apparently in fairly good condition. These include:

- coal conveyor, elevator and spreader conveyors
- coal bunkers

- coal pulverizers and associated ducts and chutes
- ash settling pits.

The boilers operate on balanced draft with air preheat and heat recuperation. Efficiency is very high (86 per cent measured 82 per cent design using gas and 84 per cent design using oil). The two stacks for the four old boilers (two boilers per stack) are 285' high. The stack for the newest boiler is 230' high. The plant was never equipped with pollution control equipment. When burning coal, complaints regarding sulphur dioxide fumes and particulate fall-out were received from nearby residences.

The plant is located on a site which, because it faces Riverside Drive, is nicely landscaped in front. Access to the rear of the plant off Wyandotte Street is fairly generous.

5.4 HIRAM WALKER AND SONS DISTILLERS

Unlike the automotive companies, the main portion of the steam production at the distillery is for process heating uses. The process heating load is 200,000 lb/hr and is fairly constant year-round. The summer heating load is 20,000 to 25,000 lb/hr and the winter heating load is about 50,000 lb/hr. These demands are expected to hold or perhaps increase gradually in the future.

The boilers produce a moderately superheated steam at 400 psig, 600°F which is expanded through turbo generators to produce electricity. Medium pressure steam (150 psig used mostly for process) and low pressure steam (20 psig used for heating) is extracted from the turbines. The power produced is used mainly by the distillery although provision has been made to produce power for the Windsor Hydro grid. Over two-thirds of the distillery's total power requirements are made up from their own turbo generators. Whenever steam demand exceeds turbine extraction capabilities, pressure reducing stations are used to make up the difference.

The boiler/power plant is operated five days per week during summer and is shut down on weekends. Summer weekend heating loads are carried on a small package boiler.

The total installed capacity of the boiler house is 440,000 lb/hr of superheated steam. There are a total of four boilers; the two oldest, of Babcock and Wilcox manufacture and installed in 1950 are of 70,000 lb/hr capacity, while the two newest of Foster-Wheeler manufacture and installed in the early 1960's are rated; one at 100,000 lb/hr and one at 200,000 lb/hr. All of the boilers were originally fired with pulverized coal and were converted to dual firing (gas/oil) in 1973.

The wet ash handling systems although basically still intact are not operational. The hopper bottoms of the furnaces have been modified for gas firing. Most of the coal firing equipment, however, is still intact and is apparently in fairly good condition. These include:

- coal pit for rail or truck deliveries
- apron conveyor
- bucket elevator
- coal bunkers with spreader conveyor
- coal pulverizers (chutes have been removed)
- steam powered ash withdrawal system and silo.

The boilers operate on balanced draft with air preheat and heat recuperation (superheaters). All induced draft fans discharge to a common breeching which leads to a single stack 212' high constructed from concrete with a steel liner. Multi-cyclones, originally installed for the coal firing system, had been removed just prior to conversion and an electrostatic precipitator of Joy manufacture was installed. Due to the conversion to oil and gas, this precipitator has never been operated.

The plant is located on the river front and is surrounded on the other three sides by either process or office buildings. Access is somewhat restricted and open space adjacent to the plant is limited.

5.5 ONTARIO HYDRO J. CLARK KEITH GENERATING STATION

The J. Clark Keith coal fired thermal electric generating station located in Windsor is owned and operated by Ontario Hydro. This station was shut down in May of 1976 and will likely remain shut down for another two to three years at least according to Ontario Hydro staff. Hydro is contemplating changing over to low sulphur coal fuel and refitting the station with new electrostatic precipitators and new 650' high stack to meet current stack emission criteria. Until restarting, the plant will remain "mothballed" with the exception of the turbo generators which are occasionally put into service as synchronous motors as a means of system power factor correction for the local Windsor grid. Consequently, there is only a skeleton staff at the station.

Prior to shutting down, the station has been used quite sparingly in recent years in keeping with Ontario Hydro's scheme that certain thermal stations will be used primarily to meet system peak demands while the base load is carried by the nuclear generating stations. Occasionally, because of low peak demands, the station would be cut back to virtually the zero power production condition for from one to three or four days. Because of this mode of operation, the overall load factor for the station was often in the order of 20 per cent. Peak balancing in this pattern could be

expected for any future utilization of this station according to current Hydro reasoning.

There are four independent boiler-turbo generator units at the station each rated at 66 megawatts. Superheated steam is generated at 875 psig and 900°F. Each boiler has a design capacity of 650,000 lb/hr of steam under these conditions. All four boilers were installed in the 1951 to 1953 period when the station was constructed. Boilers are of Babcock-Wilcox manufacture and are set up to burn pulverized coal (80 per cent passing 200 mesh) in suspension via front-mounted burners. Ash is withdrawn via hopper furnace bottom to a sluice system. Both bottom ash and fly ash (from electrostatic precipitators) is sluiced to an adjacent settling lagoon. The sluice system has been left running at low rates.

The remainder of the equipment is reported to be in good condition. This comprises:

- all of the coal handling system which include:
 - conveyors
 - a large ring grinder for raw coal size reduction
 - coal bunkers with top-loading tripper conveyor
 - air-swept pulverizers (16 - four per boiler) which grind to 80 per cent passing 200 mesh

- the induced draft and forced draft fans
- Ljungström regenerative-type air preheaters
- the boilers themselves
- multicyclone and electrostatic precipitators (in series)
- stacks (220' high) and breeching.

The boilers operate on balanced draft and, with the air preheat and heat recuperation, the design boiler efficiency is quoted to be 87 per cent. Because of age and mode of operation, the actual efficiency is felt to be in the order of 75 per cent. Station thermal efficiency is estimated to be 35 per cent.

Access to the station is excellent and a large open area adjacent to the station which is designated as coal pile area affords ample space for storage and handling of other bulk fuels as well.

6. FEASIBILITY STUDY

6.1 GENERAL

In this Section, the refuse quantities taken from the Resource Recovery Study are discussed in terms of fuel potential. Direct burning of refuse is not practical in any of the installed facilities and is, therefore, not given any serious consideration in the following. (For interest, quantities and potential steam production are tabulated below for comparison to RDF.) Gasification, because of lack of proven experience, is not given further consideration either. This process is, however, felt to hold good prospects for the future as noted previously.

Each of the four major energy users is investigated with respect to feasibility of using a form of refuse-derived fuel as a source of energy. The basic approach would be to convert and modify existing facilities.

6.2 REFUSE QUANTITIES AND CHARACTERISTICS

The following tabulated quantities of refuse available for fuel are based upon the data given in Table 6 of the Report on Resource Recovery Study for Windsor. The "raw refuse" refers to "as-received" condition. Refuse-derived fuel refers to a product resulting from the removal of ferrous metal from the raw refuse followed by air classification of

the remaining material into a "light" product and a "heavy" fraction. Either one or two-stage grinding can be used (this will be discussed later). The product may be densified by further processing and this will be discussed later. The reference to five days per week and seven days per week operation refers to the operation of the energy conversion facilities. Refuse collection and "front-end" processing are normally carried out on a five-day per week schedule.

REFUSE QUANTITIES AVAILABLE
AS FUEL IN TONS/DAY

<u>Year</u>	<u>As Raw Refuse</u>		<u>As Refuse-Derived Fuel</u>	
	<u>5 Days/Week</u>	<u>7 Days/Week</u>	<u>5 Days/Week</u>	<u>7 Days/Week</u>
1980	720	514	461	323
1985	825	589	528	377
1990	930	664	595	425
1995	1,040	748	666	479

From the literature, lower heating values are taken as follows:

Raw Refuse	2,500 Btu/lb
Refuse-Derived Fuel or Densified Refuse-Derived Fuel	5,000 Btu/lb

These values of course vary with moisture content, ash or residue concentration, etc. and should be verified using calorimetric determinations on typical samples. However,

they are considered on the conservative side for the cases under study. Using these values and assuming a conservative 65 per cent energy conversion efficiency in steam production facilities, the following equivalent steam quantities are determined from combustion of the refuse or RDF:

PROJECTED STEAM PRODUCTION FROM
REFUSE OR RDF IN LB/HR *

<u>Year</u>	<u>From Raw Refuse</u>		<u>From Refuse-Derived Fuel</u>	
	<u>5 Days/Week</u>	<u>7 Days/Week</u>	<u>5 Days/Week</u>	<u>7 Days/Week</u>
1980	89,000	63,000	114,000	80,000
1985	102,000	73,000	130,000	93,000
1990	115,000	82,000	147,000	105,000
1995	128,000	92,000	164,000	118,000
	<u>From 20% RDF, 80% Coal</u>		<u>From 50% RDF, 50% Coal</u>	
	<u>5 Days/Week</u>	<u>7 Days/Week</u>	<u>5 Days/Week</u>	<u>7 Days/Week</u>
1980	568,000	398,000	227,000	159,000
1985	650,000	464,000	260,000	186,000
1990	733,000	523,000	293,000	209,000
1995	840,000	590,000	328,000	236,000

*Rounded-off to nearest 1,000 lb/hr.

6.3 FACILITIES AT THE CHRYSLER CORPORATION

The advantages of the facilities at the Chrysler Corporation are as follows:

- Location is closest to the proposed site for the "front-end" facilities.

- Much of the existing idle coal handling facilities could be adapted to handle a RDF or a dRDF.
- Boilers are flexible as to type of fuel as they were formerly fitted with grates.

The disadvantages of the facilities at the Chrysler Corporation are:

- Summer baseloads are not sufficient to meet projected steam production in future years (see Table above and Section 5.2). As noted previously, Chrysler has embarked on an energy conservation program which would further reduce steam demand.
- Pollution control devices would have to be retrofitted at considerable expense.
- Facilities are surrounded on three sides by residential development.
- Local and in-plant traffic problems can be foreseen.

The most important point against the further consideration of the facilities at the Chrysler Corporation is the first one noted, namely insufficient steam demand for the quantities of fuel available. During an interview, a Chrysler representative did mention that there has been some consideration given to air conditioning using absorption refrigeration

which would require steam quantities above the current demands. The possible substitution of steam for direct fired gas in some of the baking ovens has also been envisaged. Neither of these concepts are, however, likely to result in immediate or short-term activity.

Therefore, for the time being, no further consideration should be given to the facilities at the Chrysler Corporation.

6.4 FACILITIES AT THE FORD MOTOR COMPANY

The advantages of the facilities at the Ford Motor Company are:

- Adequate space is available for deliveries, truck movements and additional handling facilities.
- Truck access is good.
- Boilers are somewhat flexible with respect to load as power can be generated.

The disadvantages of the facilities are:

- There is indication that Ford may discontinue generating power. Should this happen, the resulting summer base-loads would be considerably less than the projected steam production (see Table on Page 27 and Section 6.2).

- Pollution control devices would have to be retrofitted at considerable expense.
- Boilers are limited as to conversion as they were originally designed for suspension firing only.
- The facilities are more distant from the proposed "front-end" plant site than Chrysler.

As in the case of Chrysler, the most important point against the further consideration of the facilities at the Ford Motor Company concerns the possible imbalance between steam demand and projected steam production from RDF. If there were a firm policy to continue turbo generation of power, the Ford facilities would warrant more detailed study.

For the time being, no further consideration should be given to the facilities at the Ford Motor Company.

6.5 FACILITIES AT HIRAM WALKER

The advantages of the facilities at Hiram Walker and Sons Distillers are:

- Boilers are flexible with respect to load, as power can be produced at variable rates with excess being sold into the Windsor hydro grid.
- Good pollution control equipment is already installed.

- There is a good steady process steam demand that will match the projected steam production for the next 20 to 30 years at least for some firing options.
- The boiler operation is predominantly on a five day per week basis (which would match the operation of a front-end processing plant) and would avoid the need for large RDF stockpiles and multiple handling of fuel.
- There is an excellent attitude among both the engineering and the operating people interviewed regarding "energy conservation by the use of a refuse-derived fuel".

The disadvantage of the facilities at Hiram Walker is basically that of space. Distance (approximately 4 1/2 miles) from the site of the proposed "front-end" plant and traffic requirements also pose some concern. These problems are not, however, insurmountable.

It is therefore appropriate that a detailed study be carried out on the conversion of the facilities at Hiram Walker to recover the fuel value from the refuse generated in the Windsor area. This will be discussed in detail in the next Section of this Report.

6.6 FACILITIES AT J. CLARK KEITH STATION

The advantages of the facilities at Ontario Hydro's J. Clark Keith Station are:

- Even at low load factors, the station has ample steam demand to match the projected steam production regardless of the firing option.
- Pollution control equipment is installed at present. This will likely be improved in the future.
- Access and site space conditions are optimum.
- Boilers could readily be adapted to burn a form of RDF.
- It would probably be a better station for burning RDF than the presently contemplated RDF combustion facilities at the Lakeview Generating Station. This opinion is based on the fact that Lakeview is much more of a "production" station than the Keith Station. Thus, the Keith Station would be better considering the experimental nature of the "Watts from Waste" project.

The disadvantages of the facilities are:

- The station is at present shut down and there is no firm indication of when it will be put back into service.

- The station is considerably more distant (approximately 7 1/2 miles) from the site of the proposed "front-end" plant than the previously mentioned potential users.
- Hydro staff appear to be taking a "wait and see" attitude with regard to the use of RDF in their boilers. According to Hydro staff it will probably be at least 1980 before sufficient testing will have been completed at their test unit (Lakeview No. 6) and a decision taken one way or the other on the use of RDF in Hydro's boilers.

Because of the above, the possible use of RDF at the Keith Station should be given equal consideration to the use of RDF at the Hiram Walker Facilities. This will be discussed in detail in the next Section of this Report.

7. DETAILED STUDY

7.1 GENERAL

The investigation of optional approaches to conversion of the facilities at Hiram Walker and Sons Distillers and the J. Clark Keith Station are closely related to the type of fuel that can be produced at the "front-end" plant. In the following, both RDF and dRDF are considered.

7.2 REFUSE-DERIVED FUEL

Referring to the overview presented in Section 4 of this Report, there are three forms of refuse-derived fuel that are feasible to produce at present. These are:

- "coarse ground" RDF (sub-classified as "single" or "double coarse ground")
- "fine ground" RDF
- dRDF.

"Single coarse ground" RDF has a particle size of 4" to 6" and is suitable for stoker firing (pneumatic or mechanical) on travelling grates. This form of RDF may or may not have been air classified. "Double coarse ground" RDF has a particle size of 1 1/2" to 2" and is also suitable for pneumatic firing on travelling grates. Air classification is not necessary (for example, as at Hamilton, Ontario) but

will produce a higher net heating value fuel and will permit further material recoveries from the "heavy" fraction (for example, as at Ames, Iowa).

The "fine ground" RDF has an average particle size diameter of about 3/8" and maximum particle size of about 1". It is light and fluffy (loose bulk density of from 2 to 9 lb/cu ft). It is the result of fine grinding the overhead or "light" fraction from air classification. Firing is in suspension using specially designed pneumatic powered burners. This process was used at St. Louis, Missouri and initially at Ames, Iowa in conjunction with pulverized coal as noted previously. Due to experience with particles being too large to permit efficient burning, Ames has recently discontinued suspension firing and only stoker or grate firing is used at this facility now.

The densified RDF (or dRDF) can be made in either briquette or pellet form for use with either spreader stoker on-grate firing or suspension firing as a supplement to coal using a separate pulverizer to avoid starting fires with coal dust. A fine granular form for suspension firing has been developed by Combustion Equipment Associates of New York. Other than for pilot test runs, these systems are not yet used on full scale installations. The major advantage of the pellet or briquette form of RDF is that it is easily transported and handled. It is similar to coal in these regards.

Combustion Equipment Associates produce two forms of dRDF (Ecofuel I and II) but are not interested in anything other than a total commitment involvement. This would permit Combustion Equipment Associates to design, build, own and operate the dRDF facility. Combustion Equipment Associates would charge the municipality for disposal of refuse and would also receive revenue from sale of dRDF to a user. This taxonomy is not felt to be suitable for the Windsor situation at this time.

Two suppliers of equipment for RDF densification have been contacted. These are: Ecosystems Division of the Grumman Aircraft Corporation of New York and the Francis Hankin Company which handles equipment manufactured by Redman Heenan and Froude Ltd. of Great Britain. Neither supplier has responded to requests for information. However, preliminary information is that the extra cost involved with producing dRDF is in the order of \$2.00 per ton. It is assumed that delays in response to several requests are due to lack of sufficient data on performance. When data is received, an in-depth study on the suitability of dRDF for Windsor could be appended to this Report. For the discussion and recommendations made in the following Sections of this Report, no further consideration will be given to dRDF.

7.3 PLANT CONVERSION - HIRAM WALKER

The boilers were originally designed for suspension firing using pulverized coal. The modifications to the furnace bottoms carried out at the time of conversion to oil and gas were not permanent. Thus, restoration of the hopper bottoms used for suspension firing would not be difficult. This fact, plus the fact that the original boiler, flue gas, air and fuel handling systems were all designed for suspension firing would indicate that the easiest conversion would be back to suspension firing of a solid fuel.

Based upon recent experience at Ames, Iowa and St. Louis, Missouri, successful suspension burning requires fine shredding (small particle size, approximate mean size 3/8"). The power and shredder maintenance unit costs for producing "fine ground" RDF are from two to four times the unit cost of producing the 1 1/2" or 2" "double coarse ground" fuel, adding in the order of \$1.50 to \$3.00 per ton to the overall unit cost of fuel production. In addition to incurring significantly higher production costs, the "fine ground" RDF is more difficult to handle and store than the coarser varieties of RDF. Because fine ground RDF resembles confetti in nature, it is difficult to contain during shipping and conveying. In bulk storage it has a tendency to agglomerate into clumps.

A meeting was held with Foster Wheeler of St. Catharines, Ontario, the suppliers of the two larger boilers at the Hiram Walker Plant. The three possible forms of RDF that were discussed with respect to compatibility to boiler adaptation were:

- "fine ground" (1/4" to 3/8" air classified) for suspension firing
- "double coarse ground" (1 1/2" to 2" air classified) for firing on grates
- "single coarse ground" (4" to 6" not necessarily air classified) for firing on grates.

Foster Wheeler felt that only the larger (200,000 lb/hr) boiler could be considered for adaptation for any of the above. The smaller boiler (100,000 lb/hr) did not have sufficient furnace size or geometry to permit the installation of a grate and the baffled flow superheater would be very prone to gas side fouling - especially when suspension firing.

For the 200,000 lb/hr boiler adaptation, Foster Wheeler felt that the most feasible approach would be to install a relatively small grate in the lower portion of the hopper bottom and to fire the refuse as 1 1/2" to 2" size pneumatically below the existing front-mounted burners. The existing dual

fired oil/gas burners would have to be converted back to pulverized coal firing to achieve the desired performance. It was felt that a 25/75 per cent blend of RDF and pulverized coal could be used as fuel. When it was pointed out that Ames was burning 50/50 on Riley grates, Foster Wheeler (who were at one time exclusive representatives for Riley in Canada) felt that perhaps a 50/50 blend may be feasible for this application, although the 25/75 blend would be preferred.

The following modifications would be necessary for the 200,000 lb/hr boiler to burn RDF:

- Install a small travelling grate in the lower section of the hopper bottom of the furnace, approximately 13' below the lower firing ports.
- Install pneumatically powered stoker above this grate.
- Installation of the grates would necessitate cutting off and removing bottom sections of tubes in the radiant section, the installation of new bottom headers and a revision to water circulating tubes.
- Seal off existing hopper bottom and install new refractory-lined ash conduit to discharge to existing ash withdrawl system.
- Install additional air supply for grate.

- Modify boiler combustion controls.
- Modify soot blower system.
- Replace oil/gas burners with coal guns.

A rough order of magnitude cost estimate for the above modifications was given by Foster Wheeler as \$1,000,000. It should be noted that, even with this expenditure, the boiler would have to burn approximately a 35/65 blend of RDF/coal initially in order to meet the projected fuel production rate. This would rise to approximately 50/50 by 1990 and would require burning even greater percentages of RDF than coal after 1990.

In view of the above, it is not felt that the Hiram Walker Plant can offer the long-term market for RDF that is required to justify proceeding. This, of course, could change if say a second large (200,000 lb/hr boiler) were to replace some of the smaller existing steam generating facilities. To ascertain feasibility of pursuing this option, more detailed studies and negotiations with Hiram Walker would be necessary. It should be noted that in addition to the cost of any new boiler facilities, an allowance for the cost of RDF handling and storage facilities and reinstating coal storage and handling system at Hiram Walker would also have to be included in any future economic studies. Economics could very likely

discourage pursuit of this alternative unless some government funding was available.

Because of the unpromising outlook with regards to both technical and economic feasibilities, prime consideration should not be given to converting boiler facilities at Hiram Walker for burning RDF at this time.

7.4 PLANT CONVERSION - ONTARIO HYDRO J. CLARK KEITH STATION

As noted previously, the boilers are all equipped for suspension firing of pulverized coal. The plant is at present "moth-balled". In spite of the age of the boilers (23 to 25 years), it is reported that all facilities and equipment are in generally good operating condition. An exception to this generalization must be made for the precipitators which cannot meet current emission standards.

A meeting was held with technical representatives of the Babcock Wilcox Company, suppliers of the boilers, to discuss the various aspects to adaptation of the boilers to burn a refuse-derived fuel. Three possible forms of fuel were considered:

- "fine ground" (1/4" to 3/8", air classified) for suspension firing.

- "double coarse ground" (1 1/2" to 2", air classified) for firing on grates.
- "single coarse ground" (4" to 6", not necessarily requiring air classification) for firing on grates.

The negative aspects of fine grinding, primarily extra cost and difficulties with handlability noted in the previous Section, were discussed. Technical and overall economic implications mitigated against further consideration of suspension firing of "fine ground" RDF.

Based upon their experience, the Babcock Wilcox representatives anticipated no problems with burning on grates, even though it meant perhaps more extensive modification to the boiler bottom section. Grate burning also avoids problems of slagging on radiant section tubes and plugging of superheater tubes that are prevalent in suspension burning systems. Also, generation of fly ash, always a potential problem in suspension firing, is diminished by properly controlled combustion on grates. It was also felt that it would be preferable to burn an RDF which had a particle size of about 2". Air classification would be a desirable step in the processing of the fuel as it would improve the heating value, eliminate many of the problem-causing materials in the raw refuse (e.g., glass, rubble, etc. which tend to form slag in the furnace).

The Babcock Wilcox boilers at the J. Clark Keith Station could be adapted to burn up to 10 to 20 per cent "double coarse ground" RDF in combination with pulverized coal by carrying out the following modifications:

- Install a travelling grate not less than 14' below existing coal firing ports. (This would ensure grates would not overheat.)
- Install new wind swept spout stokers in furnace wall to feed RDF to grates.
- The installation of the grates would necessitate cutting off and removing bottom sections of tubes in the radiant section and installation of new bottom headers.
- Seal off existing hopper bottom and install new refractory-lined ash conduits to discharge to existing ash sluice system.
- Install additional air supply for grate.
- Modify boiler combustion controls.
- Revise upper ash collection hoppers (from experience gained at SWARU).
- Improve soot blower systems.

A rough order of magnitude cost estimates for the above modifications was given by Babcock Wilcox as one million dollars for one boiler at the Keith Station. Although one boiler could quite easily consume all of the RDF produced (provided station duty factor is at least 25 per cent), it would probably be advisable to convert two boilers. This would ensure combustion of the fuel would continue even during a boiler shut-down or equipment breakdown and/or maintenance. Before the second boiler conversion, it would be advisable to carry out extensive testing on the first conversion to uncover any potential problem areas requiring additional design modifications.

The RDF handling and storage facilities required at the station would include:

- a dumping pit (for transfer trailers)
- a loading conveyor
- a live bottom storage silo
- a pneumatic conveying system to the boiler(s).

The storage and handling facilities are estimated to cost 2 million dollars installed.

Thus, the total cost of converting one boiler plus installing all of the RDF handling and storage systems at the J. Clark Keith Station is estimated to be 3 million dollars.

Based upon the findings of this Study, consideration should be given to discussing conversion of one unit at the Keith Station with Ontario Hydro staff. It would appear that the Keith Station has, in fact, some significant advantages over the Lakeview Station for conducting combustion/power generating tests which would form part of the "Watts from Waste" study. These are:

- There is a staff complement who could devote their full time to operating a boiler during testing. At Lakeview, the prime concern is power production to meet demands on the station.
- The boilers at Keith are more readily adaptable to RDF firing (in the opinion of Babcock Wilcox staff).
- The experimental boiler could be used to burn RDF from the City of Windsor after completion of the test runs.

The disadvantage of the Keith Station is that RDF for the initial testing would have to be shipped from the Ministry of the Environment, Resource Recovery Experimental Station at Downsview. For this case, rail shipment of RDF would be warranted until a Resource Recovery Plant is constructed at Windsor.

Should the Keith Station be considered for testing, it would be advisable to design the precipitator associated with the test boiler to take into account the slight variations in particulate loading and resistivity resulting from combustion from a 20 per cent RDF/coal blend.

7.5 ECONOMIC CONSIDERATIONS

The following analysis conforms to the reasoning outlined in Section 6.3 in the "Windsor Area Resource Recovery Study - Final Report" prepared by M. M. Dillon Limited.

The annual Capital Recovery Income Requirement (CRIR) for converting, adapting and operating the RDF facilities at the Ontario Hydro Keith Station would be calculated as follows:

Annual debt retirement charges (40 year financing at 10% interest)	\$306,000
Manpower (assume RDF facilities require an extra 8 man-hours/day)	30,000
Power (100kW for year at \$.02/kWhr)	18,000
Maintenance and spares	<u>60,000</u>
Total Annual Capital Recovery Income Requirement	<u>\$414,000</u>

The earliest year that a system could be considered operational would be 1980. Therefore, the CRIR inflated to 1980 dollars would be \$542,000.

In 1980, approximately 120,000 tons of RDF with a total heat value of 1.2 billion Btu's will be available. Reducing the CRIR to a unit price per million Btu's results in a CRIR of \$0.45 per million Btu for the initial year.

From discussions with Hydro staff, the cost of coal for all coal fired thermal stations in Ontario averages \$1.33 per million Btu's laid down at the plant. Projecting an average price increase of 8 1/2 per cent per annum (which was the average over recent years), coal would be expected to cost \$1.84 per million Btu's in 1980. Note that this is delivered cost. Cost of pulverizing and delivering coal to boiler would increase this figure approximately \$.02 per million Btu's.

Therefore, if the RDF had a "zero cost", there would be a considerable incentive (\$1.86-\$0.45) of \$1.41 per million Btu's to proceed with adapting their facilities to burn RDF.

However, the RDF is not produced at a zero cost. In preparing the "Windsor Area Waste Management Study - Final Report", a revenue from sales of RDF of \$8.00 per ton of raw refuse processed was used. In 1980, it was projected that 175,000 tons of raw refuse would be processed which would result in a revenue of \$1,400,000. The heat value in the processed RDF fraction was previously given as 1.2 billion Btu's which translates to a selling price of \$1.16 per million Btu's.

The margin between the selling price for RDF and the cost of conventional fuel (coal) reduced by the CRIR is:

$$\$1.86 - .45 - 1.16 = \$.25 \text{ per million Btu's}$$

Thus, RDF purchased from the processing plant in Windsor would be approximately 14 per cent cheaper than coal, figuring a purchase cost of \$1.16 per million Btu's and a CRIR of \$.45 per million Btu's.

The station could burn a 20 per cent RDF/80 per cent coal mixture and if station duty factor was about 20 per cent (as it has been in recent years), the result would be an overall reduction of about 2.7 per cent in the annual fuel cost for the station. This would amount to in the order of \$300,000 per year and would increase in magnitude as the cost of fossil fuels increase over the years.

8. CONCLUSIONS AND RECOMMENDATIONS

8.1 CONCLUSIONS

From the investigations and studies carried out for this Report, two alternatives have been identified for the recovery of energy from refuse by adaptation of existing facilities at Windsor. The locations of the facilities are:

- Hiram Walker and Sons Distillers
- Ontario Hydro's J. Clark Keith Thermal Generating Station.

Facilities at both alternative locations could most feasibly be adapted by converting a boiler by the installation of grates, modification of the ash system and provision of a refuse storage, handling and feeding system. Other minor considerations have been discussed in detail along with the above noted major ones in Section 7 of this Report. Combustion of the refuse-derived fuel would be basically on the grates, especially at higher RDF to coal mixtures. Fuel specifications would call for air classification and ferrous metal removal from the raw refuse. Grinding to a particle size of about 1 1/2" is also called for.

Each location has its drawbacks. At the Hiram Walker facilities, only the largest boiler could be readily adaptable to firing RDF. Because of this fact, this facility could only

handle projected fuel quantities for a few years into the future. Long-term fuel production projections would exceed the capacity of the facilities to burn all of the fuel. To meet long-term conditions, new boiler facilities would have to be added.

On the other hand, while the facilities at the Keith Station are large enough to serve as a long-term user of RDF, one major problem persists. The plant is currently "in moth-balls" and no firm plans have been established by Hydro for its destiny.

Technical feasibility has been shown for both alternatives in the short-term. Technical and economic feasibilities for Hydro for both the short and long-term are also indicated. However, no definite recommendation for construction of facilities can be made at this time.

8.2 RECOMMENDATIONS

The outcome of the study would indicate the following recommendations are in order:

1. A joint meeting between involved staff members of Ontario Ministry of the Environment, Ontario Hydro, City of Windsor and M. M. Dillon Limited should be held to review and discuss the findings and implications of this Report.

2. Consideration should be given to conducting experimental test runs at the Keith Station on burning of a "double coarse ground" RDF on a grate in combination with pulverized coal in one boiler. Test runs should extend at least over a six-month period and preferably longer (perhaps two years) with full monitoring of all important variables. Tube wastage data would be more reliable from longer test periods. These test runs could be done in addition to, or in lieu of, the testing contemplated for the Lakeview Generating Station.
3. Should a lack of interest be encountered with Hydro, consideration should be given to the Hiram Walker alternative. In this case, the findings of this Report should be discussed with Hiram Walker management staff. Because of equipment limitations and constraints, more capital would have to be spent to provide facilities suitable for long-term conditions (for example, a new 200,000 lb/hr boiler and reconversion of existing boiler to coal firing).
4. If the Hiram Walker alternative develops, potential avenues for financial assistance in constructing capital works for experimental purposes could be investigated. This could take the form of grants or interest-free

loans from such higher government agencies as the Provincial Ministries of Energy, and Environment and/or their Federal counterparts.



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